THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

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PHYSICAL AND MECHANICAL PROPERTIES OF 'K' MONEL

'K' Monel is a modification of standard Monel, containing 2·75% aluminium, which enables its properties to be improved by heat-treatment.

Composition, *per cent.*

	Nominal	Specification Range	
		Min.	Max.
Nickel	66	63	70
Copper	29	remainder	remainder
Aluminium ..	2·75	2	4
Iron	0·90		2
Manganese ..	0·40		1
Carbon	0·15		0·25
Silicon	0·25		0·50
Sulphur	0·005		
Other Metals ..			1

Physical Properties

Specific Gravity	8·47
Density, *lb./cu. in.*	0·306

Electrical Properties

Electrical Resistance*	
microhms/cm/sq. cm.	62·0/62·8
ohms/cir. mil. ft.	371/378
Electrical Conductivity, *per cent.* (copper = 100) ..	3
Temperature Coefficient of Electrical Resistivity (20°-100°C.)	0·0019

* Higher value for material quenched after hot-rolling or forging; lower for heat-treated material.

Magnetic Properties

Magnetic Transformation Point	below −100°C.

Thermal Properties

Melting Range °C.		1315-1350
Specific Heat ..	20°–400°C.	0·127
Thermal Conductivity *c.g.s. units* ..	0°–100°C.	0·045

Thermal Properties (*contd.*)

Coefficient of Thermal Expansion
millionths per deg. C.

at 20°C.	13·0
100°C.	14·0
200°C.	15·4
300°C.	16·7
400°C.	18·0
500°C.	19·3
600°C.	20·8

Average Coefficient of Thermal Expansion
millionths per deg. C.

0°–100°C.	13·2
0°–200°C.	14·0
0°–300°C.	15·1
0°–400°C.	15·3
0°–500°C.	15·9
0°–600°C.	16·5

Modulus of Elasticity

millions of lb. per sq. in.

In Tension or Compression	26
In Torsion or Shear	9·5
Poisson's Ratio	0·32

Table I

Grades of 'K' Monel

'K' Monel is obtainable in six standard grades, chief characteristics of which are as follows:—

Grade	Description
A	Material in hot-rolled, extruded or forged condition, whether finally annealed or not.
B	Grade A material which has been hardened by thermal treatment.
C	Material in the cold-worked condition, not thermally hardened.
D	Thermally-hardened Grade C. Hardest form of 'K' Monel.
E	Material which has been cold-worked and annealed.
F	Thermally-hardened Grade E.

Mechanical Properties at Normal Temperatures

Table II

Typical Tensile Values for Sections in Various Grades

	Grade A	Grade B	Grade C	Grade D	Grade E	Grade F
	Rod, Round, Square, Hexagon and Flat		Rod, Wire, Tubing and Strip			
	Hot-Rolled, Extruded or Forged.	Hot-Rolled, Extruded or Forged, Thermally Hardened	Cold-Worked	Cold-Worked Thermally Hardened	Cold-Worked Softened	Cold-Worked Softened and Thermally Hardened
0·2% Proof Stress, *t.s.i.*	18—38	44—53	31—44	44—58	18—26	40—49
Maximum Stress, *t.s.i*	40—53	60—71	44—55	62—75	40—49	58—67
Elongation on $4\sqrt{\text{Area}}$, %	45—30	30—20	35—15	30—15	45—35	30—20
Hardness, D.P.N.	160—240	275—315	190—265	280—340	155—195	260—280

Table III

Typical Tensile Properties of Spring Strip and Wire

	Cold-Rolled Strip		Cold-Drawn Wire	
	Grade C Full Hard	Grade D Full Hard Thermally Hardened	Grade C Full Hard	Grade D Full Hard Thermally Hardened
Limit of Proportionality, *tons/sq. in.*	—	—	27—31	31—38
Maximum Stress, *tons/sq. in.*	65—74	76—89	65—78	76—89
Elongation on 2 in., *per cent.*	8—2	10—2	4—2	8—3

Table IV

Comparison of Strength in Shear and Tension

	C	D	E		F	
	Full Hard	Full Hard Thermally Hardened	Soft	Half Hard	Soft Thermally Hardened	Half Hard Thermally Hardened
Properties in Double Shear:						
Maximum Stress, *tons/sq. in.*	39·5	44·0	29·0	31·5	43·0	44·0
Deflection at Maximum Stress	0·04	0·04	0·08	0·04	0·06	0·05
Tensile Properties:						
Maximum Stress, *tons/sq. in.*	67·5	75	43·5	54·5	65·5	69·5
Elongation in 2 in., *per cent.*	16·5	12·5	49	12·5	29	24
Ratio of Maximum Stress in Shear to Tension	0·58	0·59	0·60	0·58	0·66	0·63

Table V

Comparison of Strength in Compression and Tension

	Grade			
	A	B	C	D
Compression				
0·1% Proof Stress, *tons/sq. in.* ..	15	43	25	45
0·2% Proof Stress, *tons/sq. in.* ..	18	54	34	54
Tension				
0·1% Proof Stress, *tons/sq. in.* ..	18	43	32	46
0·2% Proof Stress, *tons/sq. in.* ..	21	49·5	38	53·5
Maximum Stress, *tons/sq. in.* ..	45	67	47	70·5
Elongation in 2 in., *per cent.* ..	42·5	30·0	26·5	22·0
Reduction of Area, *per cent.* ..	63·5	44·5	50·5	37·5
Hardness, D.P.N.	170	340	218	380

Table VI

Izod and Charpy Impact Strength

	A Hot-Rolled	B Hot-Rolled Thermally Hardened	C Cold-Drawn	D Cold-Drawn Thermally Hardened
Impact Strength, *ft.-lb.*				
Izod	120	40*	56*	26*
Charpy ..	170	61*	71*	42*

* Completely broken specimen.

Table VII

Endurance Limit

	Grade A		Grade B Hot-Rolled Hardened	Grade C Cold-Drawn		Grade D Cold-Drawn Hardened
	Annealed	Hot-Rolled		As-Drawn	Stress-Equalized	
Endurance Limit for 10^8 Cycles, *tons/sq. in.*	17—18	18—22	20—26	19	18·5—21	18—26·5
Tensile Strength, *tons/sq. in.*	40—41	42·5—45	62·5—70·5	48·5	47·5—49	66·5—73·5
Endurance Ratio	0·42—0·45	0·43—0·48	0·28—0·41	0·41	0·39—0·42	0·26—0·36

Mechanical Properties at Low Temperatures

Table VIII

Tensile and Impact Properties of Grade D 'K' Monel, Cold Drawn, Thermally-Hardened Rod

Temperature °C.	0·2% Proof Stress *tons/sq. in.*	Maximum Stress *tons/sq. in.*	Elongation in 2 in. *per cent.*	Impact *ft. lb.*
Room	56	70·2	15·5	27
−79	60	76·5	17·3	27
Room*	56	70·3	14·8	26

* Cooled to, and held at, −79°C. for several hours prior to testing at room temperature.

Mechanical Properties at High Temperatures

Table IX

Short-Time, High-Temperature Mechanical Properties of Two Grades of 'K' Monel
Grade A—Hot-Rolled; Grade B—Hot-Rolled, Thermally Hardened

Temperature °C.	0·2% Proof Stress		Maximum Stress		Elongation in 2 in. per cent.	
	Grade A	Grade B	Grade A	Grade B	Grade A	Grade B
Room	24·5	49·5	43·5	71·5	44·0	23·5
93	20·0	48·0	43·0	67·0	42·5	23·5
204	19·5	46·0	41·0	66·5	42·0	24·0
316	16·0	47·0	42·0	65·0	39·5	23·0
426	17·5	47·0	39·0	55·5	29·5	8·5
537	19·0	41·0	32·0	42·5	13·5	3·0
650	19·5	36·0	28·0	36·0	2·5	1·5
760	7·5	13·5	16·0	20·0	22·5	8·0
814		3·5	13·5	14·5	32·5	15·0
871			6·7	9·5	53·0	23·0
982			4·5	2·7	65·5	47·5
1,093				1·3		81·5

Heat-Treatment

Table X

Heat-Treatment Chart

Treatment	Material, Condition or Grade	Heat to Temperature °C.	Time at Temperature	Rate of Cooling
Regular Anneal for Softening	Cold-Worked	870	2-5 minutes	Quenched whenever possible. Sections over ½ in. must be quenched.
		980	1-3 minutes	
Age-Hardening Treatment	Hot-Rolled Material	580	6 hours	Furnace cool.
	Cold-Drawn Material	560	4 hours	Furnace cool.
	Solution-Treated Material which has been heated for 15-20 mins. at 950°C., followed by water-quench	585	6 hours	Furnace cool.
Stress-Equalizing Treatment	Material cold-worked after age-hardening (Grade D) or cold-worked parts which are *not* to be age-hardened (Grade C)	300-345	1-2 hours	Quenched or furnace cooled.

ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Softening of Metals during Cold Working: Behaviour of Nickel-Copper Alloys

N. H. POLAKOWSKI: 'Softening of Metals during Cold-Working.' *Jnl. Iron and Steel Inst.*, 1951, vol. 169, Dec., pp. 337-46.

The investigation reported (carried out with the aid of a grant from the Andrew Carnegie Research Fund) was undertaken with a view to elucidating the following effects, and studying possible inter-relationships:—

(1) The recrystallization temperature of a metal usually decreases with increasing cold work, but a reversal of the direction of deformation causes an increase of the recrystallization temperature over that at the end of the first straining, indicating that the metal has softened during the reversal. It is, however, claimed that work-hardening, as shown by mechanical properties, should continue to increase in spite of the raised recrystallization temperature and the Bauschinger effect.

(2) Deep-drawing practice has shown that 'reversed drawing' facilitates deeper draws without interstage annealing than the unidirectional method. It is also known that unidirectionally rolled sheets are harder than those whose direction of rolling is altered after each pass.

(3) In carbon and low-alloy steels heat-treated to over 300 D.P.H. the slope of the hardness-deformation curve is low or even negative in the early stages of deformation.

The experimental work done by the present author was initially concentrated on the behaviour of steel and some non-ferrous alloys subjected to large reversed deformations, but the programme was later extended to include compression tests on heat-treated steels (300-500 D.P.H.), as well as a series of rolling tests on hardened and tempered steel strip. The non-ferrous metals used were Monel, copper, aluminium, phosphor bronze, 70-30 brass and 80-20 copper-nickel. Their behaviour was shown closely to resemble that of steel.

The selected materials, initially overstrained by tension, torsion, or drawing, were progressively compressed in a direction opposite to that of the initial flow. In each case not only was a Bauschinger effect observed, but also an initial gradual decrease of the indentation hardness (by amounts up to 10 per cent.), before it increased. Both effects were reproducible, and were more pronounced in the higher-carbon than in the lower-carbon steels.

A theory relating indentation hardness and the energy stored in a cold-worked metal is put forward as a tentative explanation of both the Bauschinger effect and work-softening. To satisfy this theory quenched and tempered steels should soften during the early stages of cold-working, a characteristic which has been verified experimentally. This energy concept accounts for the low rate of work-hardening during reversed- and cross-rolling of sheets, and reversed deep-drawing, and also during cold-working and fatigue-testing of heat-treated, i.e., sorbitic and troostitic, steels. The softening effect provides an explanation of the recrystallization and mechanical properties of single- and poly-crystalline metals after reversed deformation.

Standard Specifications for Testing of Metals

BRIT. STANDARDS INSTN.: 'B.S. Mechanical Tests for Metals (excluding Welds).' *B.S. Handbook No.* 13, 1951, published Dec., 1951; 243 pp.

In 1932 a technical committee was appointed, under the authority of the Engineering Council, with the following terms of reference:—

> 'To co-operate with and advise the various technical committees of the Institution engaged in the preparation of B.S. specifications which include requirements relating to mechanical testing; also, to endeavour to bring about co-ordination in the methods of testing laid down, with the object of eliminating unnecessary variations in testing requirements in B.S. specifications.'

This committee, through the medium of specialist sub-committees, has been responsible for preparation of a number of new specifications on standard methods of mechanical testing, which embody the results of a considerable amount of experimental research.

The handbook now issued brings together all methods of mechanical testing which have been established in the form of British Standards and also contains relevant extracts from other standards which include clauses on mechanical testing. The scope and method of arrangement of the schedules are indicated below:—

Section 1. *Tensile Tests* (B.S. 18 and 3A.4)

British Standards for tensile testing; relationship between results from British and Continental standard test pieces for ferrous metals; tensile testing of steel wire, chain, and wire ropes.

Section 2. *Hardness Tests* (B.S. 240, 427, 891, 860)

Equipment and methods for Brinell and Diamond-Pyramid hardness testing; direct-reading hardness testing, Rockwell principle; approximate comparison of hardness scales (Diamond-Pyramid, Brinell, and Rockwell).

Section 3. *Impact Tests* (B.S. 131, 3A.4, 1349, 103)

Standards for notched-bar test pieces; test pieces and test methods for aircraft metallic materials; impact testing of cast iron; correlation of Izod and Charpy test results; drop test; pendulum impact test for rails; falling-weight test.

Section 4. *Ductility Tests* (B.S. 1639, 3A.4)

Notes on the simple bend test; ductility testing of aircraft materials; torsion and wrapping tests for wire; reverse-bend test; bending, flattening, and dump tests for rivets; drift, flanging, flattening and bending

tests for tubes; quench or temper bend test; hot- and cold-bend tests and up-ending tests for chain links; expanding tests for wrought iron wheel centres; ram's horn test; forgeability test.

Section 5. *Tests on Thin Metal* (B.S. 485)

Tests on thin metal sheet and strip material (not exceeding 0·128 in. (10 S.W.G.) in thickness).

Section 6. *Creep Tests* (B.S. 1094, 1271, 1686, 1687, 1688)

Short-time testing of light alloys at elevated temperatures; proof test for quality of carbon-steel boiler plate; equipment and methods for (1) long-period, high-sensitivity tensile creep testing, (2) medium-sensitivity tensile creep testing, and (3) determination of time to rupture under stress, with or without measurement of creep strain.

Section 7. *Verification of Testing Machines* (B.S. 1610)

Methods of load verification; verification of tensile and compression machines.

Section 8. *Transverse Test* (B.S. 1452)

Testing of grey-iron castings.

Section 9. *Miscellaneous Tests*

Tests on springs; crushing tests on tubes; bending tests on steel tubular traction poles; nicked-bend and fracture tests; tensile and elasticity test on cast-iron piston-ring pots (B.S. 4K.6).

Section 10. *Conversion Factors*

Conversions of British and metric weight, length and other units, and miscellaneous conversion factors.

NICKEL

Expansion of Nickel Production

'Inco Tells What it Takes to Open Up a New Ore-body.' *Engineering and Mining Jnl.*, 1951, vol. 152, Nov., pp. 96-8.

The International Nickel Company of Canada, Ltd., announces simultaneous completion of two projects involving total expenditure of 17 million dollars:—a new shaft and a new concentrator at its Creighton Mine in the Sudbury District of Northern Ontario. Thirteen shafts are now operating in the underground mines of the Company, and the new mill, which concentrates ore before transportation to the smelter at Copper Cliff, has a capacity of 10,000 tons of ore per day. The additional underground ores will serve as replacement of open-pit ores, and will enable the Company to continue production of refined nickel at the present rate of 250 million lb. per annum.

Completion of these two projects marks a big advance towards fulfilment of the Inco 10-year programme of expansion in underground mining operations. When the programme is completed the Company's underground mines will be able to deliver 13,000,000 tons of ore annually, as compared with 5,700,000 tons of underground ore hoisted in 1950.

This article describes the new shaft, and gives details of outstanding features of the concentrator plant, e.g., crushing and grinding methods and equipment, flotation processes, dust-control procedure, sampling and assay practice, and the electrical services of the plant.

H. L. WALDRON: 'Sherritt Gordon Develops Lynn Lake Nickel-Copper.' *ibid.*, pp. 72-8.

Story of prospecting at Lynn Lake (with ultimate discovery of the existence of sulphide ores), followed by notes on the ammonia-leaching extraction process worked out at University of British Columbia for treatment of the ores. This process is characterized by low operating cost, high recovery of cobalt, and recovery of sulphur as ammonium sulphate. A 'time-table', covering start of construction of the refinery in 1952, through to full production in 1955, shows an estimate of annual production, under full-scale conditions, of 8,500 tons of nickel, 4,000 tons of copper, 300,000 lb. of cobalt, and 70,000 tons of ammonium sulphate.

Evaporated Nickel Catalysts

J. H. SINGLETON, E. R. ROBERTS and E. R. S. WINTER: 'The Reaction Between Deuterium and Ammonia on Evaporated Metal Catalysts.' *Trans. Faraday Soc.*, 1951, vol. 47, Dec., pp. 1318-31.

The exchange reaction was examined on evaporated films of iron, tungsten and nickel, at temperatures above 500°K. (227°C.). It was found that iron and nickel catalysts can, after sintering, be used for long periods without change in activity: tungsten catalysts heated to 700°K. (427°C.) in vacuo or in the presence of reactants exhibited a slow increase in activity. The effect of variations in the pressure of ammonia was examined: accurate values for the energy of activation of exchange are recorded for each of the metals. The authors also present some observations on poisoning of the catalysts.

Determination of Nickel with *Vic*-Dioximes

R. C. FERGUSON: 'Spectrophotometric Determination of Nickel with *Vic*-Dioximes.' *U.S. Atomic Energy Commission Report ISC*-93, June 5, 1950.

Literature on the colorimetric, photometric and spectrophotometric determination of nickel is surveyed, and the more commonly used reagents are discussed.

The author reports a study of the nickel-dioxime complexes which form in the presence of strong oxidizing agents. Three *vic*-dioximes were reacted with nickel under strongly oxidizing conditions, and their absorption spectra were compared. The applications of these reactions to colorimetry are discussed.

The application of the red nickelous nioxime complex to the colorimetry of nickel was studied spectrophotometrically; the absorption spectrum, stability, sensitivity to *p*H, obedience to Beer's law, and possible interferences are discussed. A procedure for determination of nickel in calcium metal, by the selected method, is detailed.

A paper based on the work described in this report was published in *Analytical Chemistry*, 1951, vol. 23, Mar., pp. 448-53; *Nickel Bulletin*, 1951, vol. 24, No. 6, p. 130.

Antimony Trichloride Substitution Compounds with Nickel Carbonyl

G. WILKINSON: 'Antimony Trichloride Substitution Compounds with Nickel and Iron Carbonyls.' *Jnl. Amer. Chemical Soc.*, 1951, vol. 73, Nov., pp. 5502-3.

Previous studies by this author and his colleagues have led to the characterization of the tetrakistrihalogenophosphine compounds $Ni(PX_3)_4$, formally analogous to nickel carbonyl. Stability decreases from the volatile PF_3 compound, through the non-volatile PCl_3- and PBr_3- compounds. The present paper reports efforts made to produce similar compounds by the interaction of antimony trichloride with nickel carbonyl and iron pentacarbonyl, which have led to the identification of mixed carbonyltrichlorostibine products. Marked differences were observed between the properties of the antimony trichloride substitution compounds of nickel and those formed by the phosphorus halides.

Anode Polarization Effects at Nickel Electrodes in Sulphuric-Acid Solutions

D. R. TURNER: 'Anode Polarization Effects of Nickel in Sulfuric Acid.' *Jnl. Electrochemical Soc.*, 1951, vol. 98, Nov., pp. 434-42.

The paper reports a study of the electrochemical polarization effects at nickel anodes in 2*N* sulphuric-acid solutions, made to determine the electrode reactions involved. The only anode reaction occurring up to above 300 ma./cm² current density was dissolution of nickel. Above this value the nickel anodes became passive in a few seconds. Determination of the exact conditions of current density and time required to passivate a nickel anode was not possible, since the previous history of each anode exerted an appreciable influence on the results.

There was evidence of formation of an anodic film, probably nickel sulphate, at the active nickel surface, an observation which supports the Müller film theory of passivity.

Freshly deposited electropolished nickel electrodes, after cathodic polarization, became anodically passive more rapidly than electrodes which had been made anodic prior to the cathodic pre-treatment. An explanation is advanced for this effect.

Addition of chloride ions to the 2*N* sulphuric-acid electrolyte had the effect of raising the minimum current density required to passivate a nickel anode: above that minimum current density chloride ions in the solution delayed onset of passivity. This inhibitory influence is not yet completely understood, but it is suggested that the improved solubility of hydrated nickel chloride over hydrated nickel sulphate explains the fact that chloride ions added to a sulphate solution may delay onset of passivity.

The electrochemical reaction at passive nickel anodes was the discharge of hydroxyl ions. A major portion of the discharged ions was transformed to oxygen and escaped from the metal-solution interface as gas bubbles. A visible nickel-oxide film was also formed. The nickel oxide was soluble in the 2*N* sulphuric-acid solution.

A measurable delay in the polarization decay of passive nickel anodes was attributed to the gradual rate of solution of the nickel oxide, but the oscillograms showed certain peculiar waves in the decay curves which could not be explained. Molecular oxygen present in the vicinity of the electrode during anode polarization is believed to have some influence on the process of decay, and it is thought that it may be responsible for anomalous effects observed.

Vaporization Studies on Nickel Oxide

L. BREWER and D. F. MASTICK: 'The Stability of Gaseous Diatomic Oxides.' *Jnl. Chemical Physics*, 1951, vol. 19, July, pp. 834-43.

The instabilities of FeO, NiO, MnO and SiO_2 upon vaporization, and upper limits to the heats of dissociation of these oxides and of SiO were determined by effusion experiments, at 1782° and 1816°K. (1509° and 1543°C.). The results obtained indicate that NiO vaporizes largely by decomposition to gaseous nickel and oxygen, which are present in gaseous phase in higher concentrations than any gaseous NiO molecules. The upper limit to heat of dissociation of NiO(*g*) at 0°K. (−273°C.) is given as 99 kcal./mol. Data recorded by JOHNSTON and MARSHALL (*Jnl. Amer. Chem. Soc.*, 1940, vol. 62, p. 1383) on vapour pressure of NiO are reviewed.

Nickel-containing Materials in Chemical Engineering: Literature Review

See abstract on p. 50.

ELECTRODEPOSITION AND OTHER COATING METHODS

Direct Nickel Plating of Aluminium

A. G. THOMSON: 'Plating Aluminium with Nickel.' *Metallurgia*, 1951, vol. 44, Dec., pp. 308-10.

The article deals with a process developed at the Low-Temperature Station for Research in Biochemistry and Physics, Cambridge, during a study of methods for protection of aluminium from corrosion by foods and beverages.

Its essential feature is the use of a special etchant for preparation of the aluminium surface. Initially a solution containing dextrin 50 g., water 150 c.c. and trichloroacetic acid in amount to make one litre was proposed (see *Jnl. Electrodepositors' Tech. Soc.*, 1950, vol. 26, pp. 181-6; *Nickel Bulletin*, 1950, vol. 23, No. 5, p. 83), but objections were raised to this solution as being too costly, and it was further pointed out that washing in acetone (between the etching and plating operations) involved risk of fire.

Further investigation has shown that satisfactory results can be obtained by the use of a modified bath containing 25 per cent. of phosphoric acid and less trichloroacetic acid. The necessity for using acetone for rinsing has been obviated by dipping the work in nitric acid, as an oxidizing agent, followed by washing

with water (*Metal Industry*, 1951, vol. 78, p. 405; *Nickel Bulletin*, 1951, vol. 24, No. 6, p. 131).

The procedure involved in the modified process is detailed below:—

'Standard Alkali Treatment

NaOH	50 g.
Lissapol N	3 g.
Water	to 1 litre

Standard Acid Etch

HCl (conc.)	2·5 ml.
Trichloroacetic Acid (melted crystals)	50 ml.
H_3PO_4 (S.G. 1·75)	250 ml.
Lactic Acid (S.G. 1·21)	200 ml.
Lissapol N	3 g.
Water	to 1 litre

Etch for 1 minute at 75°C., increasing the time of etching when this becomes necessary.

Nitric-Acid Dip

Immerse for 15 seconds in nitric acid (1:4), then rinse in water.

*Nickel Plating**

$NiSO_4.7H_2O$	120 g.
$(NH_4)_2SO_4$	21 g.
K Cl	8 g.
Water	to 1 litre
pH	5·6-5·8
Temperature	35°C.

Plate for 1 hour and 20 minutes at a current density of 15 amp./sq. ft.'

* Bath devised by BULLOUGH and GARDAM for use in a modified form of the zincate process.

Although the method has not yet been tried out on a commercial scale, it is believed to have certain advantages over other processes, particularly with regard to the requirements of the food industry. For example, the zincate process, which has been found highly satisfactory for some purposes, has the disadvantage of involving a copper undercoating, with associated dangers of rancidity and deterioration of certain forms of food. It is also suggested that the corrosion-resisting qualities of the direct-plated material may be superior to those of material plated by the zincate process. Nickel-plated aluminium produced by the new process is considered to be potentially useful in the dairy, brewery and allied industries, and, since the method can be used on certain high-strength aluminium alloys, it is also likely that the scope of application of nickel-plated aluminium may be widened in other fields of use in which lightness, strength and corrosion-resistance are desired.

Electrodeposition of Nickel with Insoluble Anodes

W. A. WESLEY, D. S. CARR and E. J. ROEHL: 'Nickel Plating with Insoluble Anodes.' *Plating*, 1951, vol 38, Dec., pp. 1243-50; disc., pp. 1250, 1255.

Full form, with discussion, of paper presented to American Electroplaters' Society, June, 1951: see reference, from abstract source, in *Nickel Bulletin*, 1951, vol. 24, No. 11, p. 230, and abstract of related patent, *ibid.*, Nos. 9-10, p. 219.

In discussion, reference was made, by the senior author, to the method used by HOTHERSALL and GARDAM, during World War II, for deposition of nickel on the interior of tubes (see *Jnl. Electrodepositors' Tech. Soc.*, 1951, vol. 27, Advance Copy 7; *Nickel Bulletin*, 1951, vol. 24, No. 5, p. 99).

Electrodeposition of Nickel-Molybdenum Alloys

F. W. SALT: 'The Electrodeposition of Molybdenum and its Alloys.' *Murex Rev.*, 1951, vol. 1, No. 9, pp. 201-10.

A review of existing information: the accompanying *bibliography* contains 19 items. The data on electrodeposition of nickel-molybdenum alloys are based on work by HOFFMANN and HULL (*Proc. 27th Ann. Convention Amer. Electroplaters' Soc.*, 1939, pp. 45-9; *Nickel Bulletin*, 1939, vol. 12, No. 12, p. 234), and SEIM and HOLT (*Jnl. Electrochemical Soc.*, 1949, vol. 96, pp. 205-13; *Nickel Bulletin*, 1950, vol. 23, No. 1, p. 10).

German Specifications for Electrodeposited Coatings

'Testing of Electrodeposited Coatings.' *D.I.N. Specification* 50 950; *Werkstoffe und Korrosion*, 1951, vol. 2, Dec., pp. 463-4.

This specification covers microscopical determination of thickness of coating. The technique described is suitable for coatings having a thickness of more than 2μ and is to be considered as standard for reference purposes. Accelerated tests (e.g., drop tests, tests involving separation of the coating from the basis metal, X-ray tests, and other non-destructive tests) are dealt with in other schedules.

Sections of the present specification lay down procedure for preparation of the samples, grinding and polishing, etching (solutions and procedure) and method of measuring the thickness of the electrodeposited coating. The procedures described cover testing of (1) nickel and chromium on steel; (2) nickel on copper and copper alloys, also copper underlays on steel and on zinc and zinc alloys; (3) zinc and cadmium on steel; and (4) lead on steel. The etchants recommended are as given in A.S.T.M. A.219-45.

'Electrodeposited Nickel and Chromium-Nickel Coatings on Steel.' *Metalloberfläche*, 1951, vol. 3, Nov., p. B.170.

D.I.N. 50 963, of which the proposed terms are given, is a specialized addendum to D.I.N. 50 960.

It lays down requirements for minimum thicknesses of chromium (where used), nickel+copper, and final nickel coating for various grades of coating, and specifies test requirements under exposure to the salt-spray test and the ferroxyl porosity test.

'Electrodeposited Nickel-Copper and Chromium-Nickel-Copper Coatings on Zinc and Zinc Alloys.' *ibid.*, p. B.170.

D.I.N. 50 964 is also complementary to 50 960, specifying thickness requirements for chromium (where used), nickel+copper, final nickel, and copper underlay. In this case too, quality is assessed by the salt-spray and ferroxyl tests.

Anode Polarization Effects at Nickel Electrodes in Sulphuric Acid Solutions

See abstract on p. 40.

NON-FERROUS ALLOYS

Interdiffusion and Sintering in Nickel-Copper Compacts

J. M. BUTLER and T. P. HOAR: 'Unrelated Simultaneous Interdiffusion and Sintering in Copper-Nickel Compacts.' *Jnl. Inst. Metals*, 1951-52, vol. 80, Jan., pp. 207-12: *Advance Copy* 1343.

The authors describe work in which the progress of interdiffusion in copper-nickel compacts was followed by metallographic examination of the compacts, which had been stained, at room temperature, with the vapour from aqueous ammonium polysulphide. This reagent rapidly forms interference films of cuprous sulphide on copper-nickel solid solutions. The rate of film formation, and hence the colour after exposure, is sharply dependent on the copper content, making possible a semi-quantitative estimate of the progress of interdiffusion. The progress of sintering was also examined dilatometrically, by means of apparatus described earlier by the authors (*ibid.*, 1950-51, vol. 78, p. 351).

Cylindrical compacts, 5 mm. in diameter, and about 3·5 mm. long, were prepared, in the absence of lubrication, using a compacting pressure of 20 tons per sq. in. The method used was that described in the authors' earlier paper, *loc. cit.* The following powders were used:—

Nickel powder alone (details are given of its main characteristics).

A 50-50 mixture, by volume, of copper and nickel powders, mixed by tumbling.

A 50-50 mixture, by volume, of the copper and nickel powders, mixed by tumbling and then reduced in hydrogen at 310°C. for 24 hours, with constant shaking.

The compacts were sintered in a Chevenard differential dilatometer adapted for use with small specimens having up to 12 per cent. change in length, and for atmospheres other than air.

At temperatures of 500°-700°C. (i.e., below those at which sintering begins) a large expansion was observed, and production of fissures caused by unequal metallic interdiffusion. These effects were not found in pure-nickel or pure-copper compacts. At higher temperatures (700°-800°C.) sintering shrinkage, very similar to that found in copper compacts, begins: isothermal sintering at 750°C. is also very similar to that found with pure copper.

The results indicate that although interdiffusion and sintering can take place simultaneously they are not causally related, and that interdiffusion can, in the early stages of heat-treatment, produce porosity, and cause expansions which are the reverse of sintering. It is inferred from the observations made that neither interdiffusion nor self diffusion is important as a mechanism for metal transfer in the sintering of metal-powder compacts, which is believed to take place rather by plastic deformation, i.e., slip, creep, or both, of mechanically weak hot metal, under the action of surface forces.

Softening of Metals during Cold Working: Behaviour of Nickel-Copper Alloys

See abstract on p. 38.

Electrical Conductivity and Temperature Coefficient of Resistance in Nickel-Copper Alloys

M. HANSEN, W. R. JOHNSON and J. M. PARKS: 'Correlation between Electrical Conductivity and Temperature Coefficient of Resistance of Solid-Solution Alloys.' *Jnl. of Metals*, 1951, vol. 3 (*Trans. Amer. Inst. Mining and Metallurgical Engineers*), Dec., pp. 1184-9: T.P. 3189 E.

(1) A linear relationship has been found to exist between the electrical conductivity and temperature coefficient of resistance $\left\{\alpha = \frac{\Delta R}{\Delta t R_0}\right\}$ for all solid-solution components added to a given metal solvent.

(2) Each solvent metal has its own distinctive β value —defined as the slope of the electrical conductivity-temperature coefficient of resistance plot.

(3) Of the common metals, the β value is highest for silver, and progressively smaller for copper, gold, aluminium, magnesium, zinc, platinum, nickel, tin, iron, and lead.

(4) Knowledge of this relationship permits quick approximation of the temperature coefficient of resistance of a solid-solution alloy by measurement of its conductivity, or *vice versa*.

The data advanced in support of the discussion include values for nickel-copper alloys.

Nickel-Copper Alloys in Kuwait Water-Distillation Plant

W. KITSON: 'Kuwait's Distillation Plant for Domestic Water.' *Times Rev. of Industry*, 1951, Dec., pp. 22-3.

The recent development of the Kuwait oil fields has rendered essential that a good supply of domestic water should be made readily available to this region. For this purpose a large distillation plant (capacity 600,000 gallons of distilled water per day) has been erected, by the Kuwait Oil Company, at Mina-el-Ahmadi, to supply potable water to the employees of the oil company: it is also partially serving the town of Kuwait. In order to meet the needs of the town adequately, His Highness Sheikh Abdulla al Salim al Subah, the ruler of Kuwait, has authorized erection of a large distillation plant in the immediate vicinity of the town. The plant will initially have a production capacity of one million gallons of distilled water per day and is to be so planned as to make possible later expansion to a capacity of five million gallons per day.

In addition to the distilled water, which is produced from sea water, it is necessary to add sufficient salts to make the water suitable for human consumption, and for this purpose brackish water drawn from wells sunk in the desert will be used.

The design and operation of the Kuwait Oil Company's distillation plant (erected by Westinghouse Electric International Company) are described in this article. Incoming sea-water feed (pre-heated in the

main condenser) is used as cooling water in the ejector condenser, before passing to each of the effects as feed water. It is noted that the first and second effects accommodate 150 sq. ft. of heating surface consisting of 70-30 cupro-nickel tubing. Condenser tube plates are of Naval brass.

Cupro-Nickel and Nickel-Brass Coinage: Chill Effect in Cupro-Nickel Bars

'Eightieth Annual Report of the Deputy Master and Comptroller of the Royal Mint.' *Published by His Majesty's Stationery Office*, 1951; 95 pp.+index.

The report includes the usual statistics on coins minted and in circulation in U.K., coinage produced for other countries, assaying results, etc.

Erratic results obtained in assaying of bars of 75-25 copper-nickel for U.K. coinage were found to be due to a surface-chill effect. Results of analysis of the bars at various depths showed that the outside skin of a bar of this alloy, chill-cast in an iron mould under conditions used at the Mint, is enriched in copper, but that the effect extends to not more than 0·05 in. below the surface. It is therefore necessary that sample cuts or drilling for analysis should be taken only after $\frac{1}{16}$ in. of material has been removed, by filing or milling, from each broad surface of the casting.

Properties and Uses of Nickel-Aluminium Bronzes

J.S. VANICK: 'Nickel-Aluminum Bronze.' *Reprint from *Foundry*, 1951, vol. 79, Aug., pp. 98-102; Sept., pp. 108-11, 192, 195.

Issued by International Nickel Co., Inc., 1951; 11 pp. For abstract see *Nickel Bulletin*, 1951, vol. 24, No. 11, p. 232.

Machining of Nickel Silver: Recommended Procedure

L. F. SPENCER: 'How to Machine Copper Alloys.' *Machinist*, 1951, vol. 95, Dec. 1, pp. 1821-35.

Machining tools and technique are described in detail, with good illustrations. The copper-base alloys for which the recommendations are made are graded in three groups, according to their machinability (see below): procedure suitable for handling each type is set out in easy-reference form:—

Group 1. Leaded copper, leaded commercial bronze, leaded brass, butt brass, free-cutting brass, forging brass, extruded architectural bronze, leaded Naval brass, free-cutting phosphor bronze, extruded leaded nickel silver.

Group 2. Low red brass, yellow brass, Muntz Metal, Naval brass, Tobin bronze, manganese bronze, leaded phosphor bronze, leaded nickel silver, Everdur alloys.

Group 3. Electrical tough-pitch and deoxidized coppers, commercial bronze (90-10), phosphor bronzes, nickel silvers, Ambrac (75-20-5 copper-nickel-zinc), Super Nickel (70-30 cupro-nickel containing 0·4 per cent. iron), Ambraloy (aluminium bronzes), beryllium-copper, and chromium-copper.

Tabular data are included on the nominal compositions, physical properties, and fabrication of standard commercial wrought copper and copper-base alloys, and their suitability for joining by various welding, soldering and brazing operations is indicated. Typical uses of the respective materials are listed.

* *We shall be pleased to supply a free copy of this publication.*

Nickel Silver for Graduated Scales

'Alloy Cut to 0·01-in. Scale.' *Steel*, 1951, vol. 129, Dec. 3, p. 116.

Requisition, by the U.S. Government, of 12-in. scales engine-divided into graduations of 0·01-in. presented a difficult problem for the suppliers. Stainless steel, which would have appeared desirable because of its durability, caused difficulty in machining the strip, and in cutting the 1201 channels, each about 0·005 in. deep. The life of the small cutting tool making the markings was very short, although the tool was made from a special alloy. Softer materials, such as aluminium, brass or plastic, were easier to work, but would not give the required durability, and it was also found that with aluminium the grooves were not easily cleaned.

The solution to the problem was found in the adoption of a nickel silver of the following approximate composition: copper 65, nickel 18, zinc 16, lead 1, per cent. This alloy has a high machinability rating, and it was found that any burrs resulting from the tiny, close-spaced cuts would, in this material, either break clean or were easy to remove with emery cloth. The nickel silver had also a suitable colour for the purpose, a low coefficient of thermal expansion (0·0000090 per °F.), and good durability. It is noted that no lubricant is usually required in cutting the grooves, although occasionally a small amount of turpentine is applied.

Determination of Cobalt in High-Nickel Steels and Alloys

See abstract on p. 52.

Nickel-containing Materials in Chemical Engineering: Literature Review

See abstract on p. 50.

NICKEL-IRON ALLOYS

Ferromagnetism: Properties and Applications of Magnetic Nickel Alloys

R. M. BOZORTH: 'Ferromagnetism.' Published by D. van Nostrand Co., Inc., New York, Toronto and London, 1951; 968 pp.

Price 17·50 dollars: £6 10s. 0d.

This comprehensive treatise is described as 'the background knowledge that has been useful to various members of the Bell Telephone Laboratories who have been actively interested in ferromagnetism.' Such staff are in three categories: (1) physicists engaged in research on the nature of ferromagnetic phenomena, (2) those carrying on the development of new magnetic materials, and (3) engineers interested in the properties and behaviour of magnetic materials for use in apparatus. The information embodied in the book has been

drawn from the fields of metallurgy, chemistry and electrical engineering, as well as from that of physics; it comprises a unique collection of theoretical and practical material within the scope indicated.

Part I, which is introductory, deals with the concepts of ferromagnetism, factors affecting magnetic quality (composition, production, etc.), and properties affected by magnetization.

Part II, covering the magnetic properties of individual materials, includes chapters on technical and pure iron, iron-silicon alloys, iron-nickel alloys of binary and modified types, iron-cobalt alloys, other iron alloys of high permeability; other high-permeability materials (cobalt, nickel, cobalt-nickel and other cobalt alloys, nickel-aluminium and nickel-zirconium alloys, Heusler alloys and other manganese alloys, and other high-permeability alloys and elements); permanent magnets.

Part III, comprising information on magnetic phenomena and theories, includes consideration of ferromagnetism, diamagnetism and paramagnetism; the magnetization curve and the domain theory; magnetic properties of crystals; stress and magnetostriction; temperature and the Curie point; energy, specific heat and the magnetocalorific effect; relation of magnetic and electrical properties, change of magnetization with time, and the discussion of special problems in domain theory.

Part IV reviews methods used for the measurement of magnetic quantities.

Appendices contain a glossary of symbols used in the text, a table of physical properties of the elements, values of some constants of interest in this field, and reference data on the magnetic properties of some standard alloys of high permeability, correlated with their nominal composition and the names of the makers of the respective types. A very extensive *bibliography* (1842-1951) completes this comprehensive textbook.

High-Permeability Nickel-Iron Alloys in Instruments

G. A. V. SOWTER: 'Some Special Characteristics of Soft Magnetic Materials used in Instrument Manufacture.' *Proc. Instn. Electrical Engineers*, 1951, vol. 98, Part II, Dec., pp. 714-27; disc., pp. 753-8.

Paper read before the Instruments Section of the Institution, May 30, 1951.

For a general account of the properties of soft magnetic alloys the author refers to his earlier paper (*ibid.*, 1951, vol. 98, Pt. II, p. 5) and to papers contributed to the Symposium on Ferromagnetic Materials organized by the Institution in 1950 (*ibid.*, 1950, vol. 97, Pt. II, p. 118 *et seq.*). The present paper is concerned specifically with some special aspects of the behaviour of high-permeability alloys which are of particular interest in connexion with instrument manufacture. It embodies a considerable amount of hitherto unpublished work, carried out by the author and his associates.

It opens with a comprehensive list of typical applications of the soft-magnetic materials in instruments, and a figure demonstrates properties characteristic of alloys which meet the requirements of the instrument-making industry: Supermalloy, Mumetal, Radiometal and Special Radiometal, Permendur, and H.C.R. Metal. The significance of the respective magnetic properties, and the manner in which they are utilized, are discussed in sections relating to hysteresis and total-loss loops, and incremental permeability.

The properties found in the various alloys with d.c., a.c. and combined a.c./d.c. operation are indicated, and recommendations are made for the material(s) best suited for use in particular conditions. Information is also given on the spread of the magnetic characteristics of spiral cores of Mumetal, produced on a commercial scale.

A section of the paper is devoted to a.c. permeability and losses of spiral cores, rings and particular assemblies of laminations, and the adverse effect of joints in the magnetic circuits is demonstrated.

A brief description is given of a method of predicting harmonic distortion in small transformers and chokes, and curves of distortion-coefficient variation with induction are given for a number of nickel-iron and silicon-iron alloys. The very marked effect of non-uniform flux distribution on harmonic generation is studied in detail: a number of anomalies are examined, and practical recommendations are made.

Magnetostriction in nickel-iron alloys is discussed, also temperature variation of magnetic properties (properties of Mumetal and Radiometal between 15° and 100°C. are tabulated). A brief comparison is made of initial and maximum permeabilities of silicon-iron and various nickel-iron alloys, in relation to their approximate cost.

Dielectric and Magnetic Properties of Ferrites

F. WAGENKNECHT: 'On the Dielectric and Magnetic Properties of Several Ferrites at High Frequencies.' *Frequenz*, 1951, vol. 5, June, pp. 145-55; *Physics Abstracts*, 1951, vol. 54, Oct., No. 7839.

'This is the first part of an exhaustive treatment of the properties of magnesium-, manganese-, iron-, nickel-, copper-, lead- and copper-lead-ferrites prepared by various methods and measured for dielectric and magnetic properties in the region 170-3, 285 Mc/s. The FeO-Fe_2O_3 system is given special attention. Numerous tables are presented showing the influence, on the properties of the copper-lead ferrites, of constitution, heating time, sintering temperature, speed of cooling, milling time, particle size, and measurement frequency.'

Inter-Relation of Magnetic Properties and Structure in Nickel-Iron Alloys

E. JOSSO: 'Relations between the Structural Condition and the Magnetic Properties of Iron-Nickel Alloys in the Region of Ni_3Fe.' *Jnl. Physique et le Radium*, 1951, vol. 12, Mar., pp. 399-401; disc., p. 401.

Changes in specific volume associated with order $\rightleftarrows$ disorder transformations in nickel-iron alloys of the Ni_3Fe area (Permalloy region) are used to determine the equilibrium diagram of the transformation. Modifications in composition were effected by varying

the nickel content or by adding a third constituent: molybdenum proved specially useful in this connexion.

Establishment of order in these alloys is associated with rise in the temperature of the Curie point and increase in the longitudinal magnetostriction coefficient: the coefficient in the ordered state is twice that found for the disordered alloy. Changes in the Curie-point position produced by variation in the degree of ordering can be accurately determined by additions of small amounts of molybdenum.

Determination of Cobalt in High-Nickel Steels and Alloys

See abstract on p. 52.

CAST IRON

Microstructures of Cast Iron: Handbook

BRIT. CAST IRON RESEARCH ASSOCN.: 'Typical Microstructures of Cast Iron.' *Published by the Association*, 1951; 55 pp.

Price: Members, 15/-; Non-Members, 21/-.

The handbook is intended to provide, for reference and comparison, a series of photomicrographs of cast iron of types which the metallurgist and engineer are likely to meet in day-to-day work. The structures illustrated have been chosen as typical, not necessarily as being preferred for particular applications.

The 'atlas' is introduced by notes on factors affecting the microstructure (cooling rate and composition), and on the types of graphite which occur in cast iron (undercooled-, rosette-, normal flake-, inoculated flake-, streamer- or feathery-, kish-, and nodular-graphite). The effect of sulphur on graphite formation is indicated, with notes on the significance of manganese: sulphur ratios. The structure of the matrix is also discussed, including notes on occurrence of ferrite, cementite, pearlite, the phosphide eutectic, and austenite.

The main portion of the handbook consists of typical photomicrographs with short explanatory notes, arranged in sections illustrating the structures of:—

Normal Constituents of Cast Iron (matrix structures and graphite).
Typical Unalloyed Cast Irons.
Special and Alloy Cast Irons.
Malleable Cast Iron.

A short section is added on structures illustrating Typical Defects in Iron Castings, with very brief notes on the main causes of the defects shown.

CONSTRUCTIONAL STEELS

Steels in Modern Industry: Textbook

W. E. BENBOW (General Editor): 'Steels in Modern Industry. A Comprehensive Survey by 29 Specialist Contributors.' *Published, for 'Iron and Steel', by Iliffe and Sons, Ltd., London*, 1951; 562 pp. Price 42/-.

This book is the outcome of discussions by a group of metallurgists, which had centred on the need for bringing to the notice of the engineering user and designer the nature and properties of the materials currently available to meet his varied requirements. The information contained in it has been compiled as a ready-reference manual designed to present the facts in assimilable and compact form.

In order to obtain and concentrate in the book the widest possible expert knowledge in the various fields which were to be covered, the form adopted was that of a collected series of related critical reviews, prepared by a team of specialists, each review dealing authoritatively with one particular aspect of which its author had intimate knowledge.

Part I is a *general metallurgical introduction*, covering the principal types of steels, and relating their properties and structures to composition and heat-treatment.

Part II comprises a series of general articles on the *properties and characteristics of steels*, under operating conditions of stress, temperature and environment normally encountered in service. This Part also contains chapters on weldability and machinability.

Part III deals with selected and specific *user aspects* in the fields of structural, mechanical and electrical engineering. In each case a short account is given of recent achievement and present-day practice.

Part IV is devoted to some of the more important forms of *surface treatment* used on metallic materials.

Each chapter, or 'monograph', is amplified by a selected list of references to major literature. The subjects of the chapters, and their authors, are listed below:—

Part I. Introductory

W. E. BENBOW: 'Principal Types of Steels in Relation to Composition and Heat-Treatment.'

Part II. General Properties Influencing Engineering Design

J. E. RUSSELL: 'Wear: Mechanical Properties.'
A. J. FENNER: 'Fatigue.'
G. T. HARRIS: 'Creep.'
T. P. HOAR: 'Corrosion of Iron and Steel.'
W. J. BURLING SMITH: 'Scaling Resistance.'
H. O'NEILL: 'Weldability.'
K. J. B. WOLFE: 'Machinability.'

Part III. Specific User Aspects

M. SPENCER: 'Structural Engineering.'
R. CLINK and K. METCALFE: 'Aircraft and Automobile Engine Steels.'
D. A. OLIVER, G. T. HARRIS and W. H. BAILEY: 'Gas-Turbine Steels and Alloys.'
J. G. M. TURNBULL: 'Steels for Steam Turbines.'
W. B. SHANNON: 'Boilers and Piping.'
H. N. PEMBERTON: 'Pressure Vessels.'
N. P. INGLIS: 'Steels for the Chemical Industry.'
W. STEVEN: 'Tools and Dies.'
G. MURRAY: 'Cold Pressing: Stretching, Bending and Deep Drawing.'
N. F. ASTBURY: 'Electrical Steels: High-Permeability Alloys.'
K. HOSELITZ: 'Electrical Steels: Permanent Magnets.'
D. A. OLIVER: 'Electrical Steels: Non-Magnetic Steels and Cast Irons.'

Part IV. Surface Treatments

H. SILMAN: 'Protective Treatment.'
E. R. GADD: 'Surface Hardening: Nitriding.'
F. W. HAYWOOD and D. S. LAIDLER: 'Surface Hardening: Carburizing.'
P. F. HANCOCK and E. MAY: 'Surface Hardening: Flame and Induction Methods.'
'Shot Peening.' Based on information supplied by B. JONES.

Laboratory Method Simulating Oil-Cooling of Commercially-treated Steel Bars

W. STEVEN and G. MAYER: 'A Method of Simulating the Oil-Cooling of Steel Bars.' *Jnl. Iron and Steel Inst.*, 1951, vol. 169, Dec., pp. 370-6 (British Iron and Steel Research Association Paper MG/AF/252/49).

The paper describes results of experiments in which cooling curves determined from temperature measurements taken at several positions in bars of up to 5¾-in. diameter, quenched in oil, were compared with the air-cooling curves of bars up to 0·8-in. diameter. The results show that the cooling of oil-quenched bar of 1-6 in. diameter, over the temperature range within which transformation to structures other than martensite is likely to occur, can be closely simulated by air-cooling a bar of appropriate size within the limits 0·052-in. to 0·890-in. diameter.

A close equivalence relationship was established between the cooling curves of bars quenched in oil and the cooling curves derived at points along the length of an end-quenched Jominy specimen, based on a comparison of the curves at temperatures in the transformation range below about 700°C. The experimentally determined cooling curves were not in good agreement with curves calculated from the tables published by RUSSELL (First Report of the Alloy Steels Research Committee, Iron and Steel Inst., *Special Report No.* 14, 1936, pp. 149-87), but the differences between the cooling curves for the axial and near-surface positions of 2-6 in. diameter bars cooled in air agreed, over the temperature range 800°-500°C., with the 'time-lag' equation used by JACKSON and his collaborators (*Jnl. Iron and Steel Inst.*, 1944, vol. 150, pp. 211-68P).

Boron-treated Steels: Summary of Information

AMER. SOC. METALS: 'Boron Steel.' *Brochure published by the Society*, 1951; 82 pp. Price 1 dollar.

With a view to assisting the conservation of strategic alloy elements and the intelligent use of alternative steels, the American Society for Metals has issued a collection of reprints of relevant articles. Most of these are from *Metal Progress*: the scope of the contents is indicated below. Dates of original publication are shown in brackets after the titles.

'Its Later than You Think.' (1951)
Editorial urging the need for immediate economy in the use of alloy elements in steel.

'Saving Precious Alloys by Intelligent Use of Alternatives.' (1951).
Report of Panel Discussion at Western Metals Congress, Mar., 1951

U.S. METALLURGICAL ADVISORY BOARD: 'Boron Steels', (1951)*
First Report of the Panel on Substitution of Alloying Elements in Engineering Steels. The Board was appointed to advise the Research and Development Board of the U.S. Department of Defense on matters affecting use of metals.

'Boron and Alternate Steels.' (1951)
Lists issued by American Iron and Steel Institute, June and July, 1951.

R. S. ARCHER: 'Boron in Steel.'
Summary of background history of boron-treated steels. Represents a survey of knowledge existing as of late 1942, consisting of extracts from a Report on Boron in Steel, by the War Metallurgy Committee (O.S.R.D. No. 973, Serial M-18).

M. C. UDY: 'Boron in Steel.' (1947)
Summarizes results of some later work, bringing the position up to the state of knowledge as at mid-1947. Later developments are covered by the report by the Panel of the Metallurgical Advisory Board, see *, column 1 of this page.

F. J. ROBBINS and J. J. LAWLESS: 'Use of Boron Steel in Production of Hand Tools.' (1950)
Report of users' experience.

'Caterpillar's Experience with Boron Steels.' (1951)
Experience in use of boron steels for axle shafts, wheel spindles, steering knuckle arms, bolts, capscrews, studs and other parts.

P. R. WRAY: 'Boron Steels for Constructional Parts and for Carburizing.' (1951)
General discussion of properties, advantages and limitations of boron-treated steels.

'Standard Hardenability Test.'
Details of specification test piece and procedure covering the Jominy test.

See also—

W. E. JOMINY: 'Appraisal of Steels by their Hardenability. (1944)
Fundamental principles of the test, with data to support arguments for its reliability, and the validity of the evaluation of steels which may be made from results obtained by it.

A. L. BOEGEHOLD: 'Hardenability Control for Alloy Steel Parts.' (1947)
Account of the work of the Society of Automotive Engineers and the American Iron and Steel Institute, in establishment of tentative hardenability specifications for alloy steel (H-bands). Demonstration of operation of this method of specification on typical steels.

A. L. BOEGEHOLD and E. W. WEINMAN: 'Cooling of Plates and Rounds.'
Reprint of charts derived from work done, during World War II, under O.S.R.D. Contract relating to Heat-Treatment of National Emergency Steels for Use in Tanks, Combat Cars, Gun Mounts and Other Ordnance Material. Correlation of cooling rates and times between Jominy bar and plates, and between bars of various diameters.

Heat-Treatment of Boron-treated Case-Hardening Steels

K. ROSE: 'Heat Treating the Carburizing Grades of Boron Steels.' *Materials and Methods*, 1951, vol. 34, Nov., pp. 66-8.

Introductory general notes on some facts which have already been established with regard to the influence of boron in steels are followed by a more detailed consideration of some of the problems which have

arisen in the heat-treatment of the carburizing grades: 50B15, 50B20; 80B15, 80B17, 80B20, 80B25; TS 94B17 and TS 94B20.

The difficulties encountered have been mainly of two types: excessive hardenability in the core (which may result in warping and distortion), and lack of sufficient hardenability in the case to guarantee surface hardness in large sections. It has been found that these limitations can be overcome by three methods: (1) changing the alloy content, by increasing the manganese; (2) reduction in carbon content, to a level of 0·15-0·17 per cent.; and (3) slowing-down the rate of cooling, by quenching in a bath held at elevated temperature. Some curves show properties typical of some boron-treated case-hardening steels.

The article closes with notes on experiences contributed by users of boron-treated case-hardening steels, in gears, axle shafts, tractor draw bars and other components.

Surface Hardening of Steel

G. T. COLEGATE: 'The Surface Hardening of Steel. Part XI. Flame Hardening.' *Metal Treatment*, 1951, vol. 18, Dec., pp. 549-56

This instalment of the series deals at length with the principles, operation and uses of the flame-hardening process. The historical background is described (with due reference to the early investigations of Shorter), and this is followed by discussion of design of jets and mode of cooling. An account is then given of the salient features of the various flame-hardening techniques: stationary or spot-hardening method, straight-line progressive method, rotary progressive method, spinning method, and progressive method. Individual applications of the respective methods are reviewed.

The next section of the article deals with the composition and characteristics of steels and cast irons suitable for flame treatment, and with treatments necessary before and after flame-hardening. The case depth obtainable by flame-hardening plain and alloy steels and irons, and the properties of such cases, are then considered, and the advantages and disadvantages of flame-hardening are evaluated.

Softening of Metals during Cold Working

See abstract on p. 38.

Weldability of Nickel-Chromium-Manganese-Molybdenum and Other Low-Alloy Steels

J. G. BALL and C. L. M. COTTRELL: 'The Weldability and Mechanical Properties of a Series of Low-Alloy Steels.' *Jnl. Iron and Steel Inst.*, 1951, vol. 169, Dec., pp. 321-36.

Report of systematic study of the influence of composition in a series of 27 low-alloy nickel-chromium-manganese-molybdenum steels of constant carbon and molybdenum contents, four nickel-free chromium-manganese-molybdenum steels and four steels of the basis nickel-chromium-manganese-molybdenum type having additions of about 1 per cent. of copper.

All the steels were made in small high-frequency induction-furnace melts, and weldability (in the normalized condition) was assessed by a modified form of the Reeve fillet-weld cracking test. Mild-steel metal-arc electrodes were of standard BEAMA types, with rutile-base coating.

The results are shown in the form of diagrams indicating the effect of composition of the steels on weldability, and are correlated with others which indicate the mechanical strength of the steels in both the normalized and the tempered conditions. From this correlation selection could be made of the steels giving the optimum combination of weldability and mechanical strength. Microstructure of the steels was also closely correlated with their welding characteristics (a series of photomicrographs is included in the paper), and the effect of tempering temperature after normalizing, on mechanical properties and microstructure, was studied in detail in one of the steels. Evidence to support a significant relationship found in this one steel was secured from a number of others in the series.

In selecting the range of composition, consideration was given to the known deleterious influence of carbon: it was therefore kept at a constant low value (0·13-0·16 per cent.). Economic considerations placed a low limit on molybdenum, but the presence of this element was considered desirable in order to maintain high yield-stress values, without adverse effect on weldability: these requirements were met by providing for a constant molybdenum content of the order of 0·22-0·25 per cent. Copper was studied as being one of the less common addition elements, and one which would also improve yield strength without adversely influencing weldability.

From the results of the tests the following conclusions are drawn:—

'(1) Of the series of manganese-nickel-chromium-molybdenum steels containing 0·25 per cent. of molybdenum and 0·15 per cent. of carbon, that giving the best combination of weldability and mechanical strength when normalized in $\frac{1}{2}$-in. square sections should contain 0·8 per cent. of manganese, nickel, and chromium respectively.

'(2) The 0·1 per cent. proof stress of the normalized lower - alloy manganese - nickel - chromium -molyb - denum steels of the series can be much improved by tempering at 600°C. Since it is only these lower-alloy steels which have good weldability, the improvement in 0·1 per cent. proof stress is common to all the weldable steels tested.

'(3) With the higher-alloy manganese-nickel-chromium-molybdenum steels the proof stress for the greater values of extension is lowered by tempering the normalized steels at 600°C. This is because these steels have air-hardening characteristics and are therefore hardened by the normalizing treatment and subsequently softened by tempering.

'(4) The ductility of the steels in the normalized condition is improved by tempering at 600°C., and the ultimate tensile strength is lowered. These two effects are slight with the lower-alloy steels of the series.

'(5) The copper-manganese-nickel-chromium-molybdenum steels tested did not give as good mechanical strength for equivalent weldability as the manganese-nickel-chromium-molybdenum steels. Tempering these

copper-containing steels at 600°C. improves the proof-stress properties in the normalized condition.

'(6) For all the steels tested there is good correlation between the microstructure of the plates in the normalized condition and the severity of hard-zone cracking obtained under the test conditions employed. The hardness of the plate in the normalized condition also bears some relation to the severity of cracking.

'(7) With a small fillet weld (10 S.W.G. electrode) the upper limit of normalized-plate hardness for no hard-zone cracking is approximately 180 D.P.H. The upper limit of normalized plate hardness for no cracking with a large fillet weld (6 S.W.G. electrode) is approximately 210 D.P.H. These values of hardness for normalized ½-in. thick plate apply only to tests carried out at room temperature.

'(8) The results indicate that approximate limiting values of hardness permissible in the hardened zone, in order that there shall be no hard-zone cracking under the test conditions employed, are as follows:—

Steel Type	Heat-Affected-Zone Hardness D.P.H. Max.	Average max.
Mn-Cr-Mo	380	360
Mn-Ni-Cr-Mo	380	370
Mn-Ni-Cr-Mo-Cu	370	360

These results are independent of electrode size (fillet size), and may therefore be used for determining the probable weldability of steels within the range of composition examined, on structural joints of similar severity to the Reeve test.'

HEAT- AND CORROSION-RESISTING ALLOYS

Thermoelastic Properties of Nickel-Chromium Steels and Alloys

G. VIDAL, P. LESCOP and L. RAYMONDIN: 'Influence of Temperature on the Elastic Constants of Metals and Alloys.' *Rev. de Métallurgie*, 1951, vol. 48, Nov., pp. 864-74.

Introductory discussion of methods which may be used for measurement of elastic constants at elevated temperatures, followed by report of tests made under the auspices of the Société Nationale d'Etudes et de Construction de Moteurs Aéronautiques. Measurements were made, on a wide variety of metals, low- and high-alloy steels, and austenitic alloys, of Young's modulus (using the vibratory method described by Florisson), and Poisson's ratio, employing the indirect classic method developed by Kirchoff in 1870 and recently used by CHEVENARD and CRUSSARD (*Compt. Rend. Acad. Sci.*, Paris, 1942, vol. 215, p. 58). Descriptions of the apparatus used in both series of tests are given, with drawings.

The experimental data recorded include results on low-alloy nickel-chromium and nickel-chromium-molybdenum steels, and on austenitic materials of the compositions shown in the table below:—

Table

Type	C %	Ni %	Cr %	W %	Co %	Ti %	Various %
URANUS Fl ..	0·10	2·5	20	0	0	0	Cu 1·5
694 C	0·40	24	15	0	0	0	
ERA-HR 2 ..	0·13	7·5	22	0	0	0	Si 1·5
ERA-HR 1 ..	0·30	7·6	20	3	0	0	
VIRGO 81 ..	0·24	8	18	4·4	0	0	
VIRGO 92 ..	0·48	14	13	2·2	0	0	Mo 0·7
URANUS 30 ..	0·42	7	20	3·3	0	0	Si 1·7
16-25-6	0·10	25	17	0	0	0	Mo 6, N 0·15
SIRIUS HT ..	0·25	16	17	3	12	2	
S. SIRIUS ..	0·25	16	17	3	12	2	Cold-worked
ASR 1	0·36	9	18	10	12	0	
ATVS	0·15	36	11	0	0	1	Al 1
ATVS 7 ..	0·12	30	15	0	21	2	
ATGS	0·10	75	20	0	0	2	Al 2
PER 2	0·25	Bal.	22	0	0	2	Al 2
STELLITE ..	2·00	0	32	11	55	0	

Mechanical Properties of Gas-Turbine Alloys

'Approximate Strength of Important Jet Engine Alloys (Round Test Bars).' *Metal Progress*, 1951, vol. 60, Nov., p. 80B.

Tabular compilation of short-time tensile, stress-rupture and creep data, compiled from various sources, on the following materials, of U.S. production.

S-816 (Co 42, Cr 20, Ni 20, W 4, Nb 4, Mo 4, Fe 3, Mn 1·3, Si 0·6, C 0·40, per cent.).

Cast Haynes Stellite No. 21 (Co 60, Cr 27·5, Mo 5·5, Ni 2·5, Fe<2·0, Mn 1·0, Si 0·6, C<0·35, per cent.).

K-42 *B* (Ni 42, Co 22, Cr 18, Fe 13, Ti 2·6, Mn 0·7, Si 0·7, Al 0·2-0·6, C 0·05, per cent.).

Timken 16-25-6 (Fe 50, Ni 25, Cr 16, Mo 6, Mn 1·5, Si 0·9, N 0·18, C 0·09, per cent.).

Discaloy (Fe 55, Ni 25, Cr 13, Mo 3, Ti 2·0, Mn 0·7, Si 0·7, Al 0·5, C 0·5, per cent.).

19-9 *DL* (Fe 66, Cr 19, Ni 9, Mo 1·3, W 1·3, Mn 1·0, Si 0·6, Ti 0·4, Nb 0·4, C 0·3, per cent.).

N-155 *Multimet* (Fe 27, Cr 21, Co 21, Ni 21, Mo 3·2, W 2·5, Mn 1·5, Nb 1·2, Si 0·7, C 0·33, N 0·14, per cent.).

Haynes Stellite No. 25 (Co 50, Cr 20, W 15, Ni 10, Fe<2, Mn 1·5, Si 0·5, C 0·10, per cent.).

Inconel X (Ni>70, Cr 15, Fe 7, Ti 2·5, Nb 1·0, Al 0·7, Mn 0·65, Si<0·50, Cu 0·2, C 0·08, per cent.).

Nimonic 80 (Ni 75, Cr 21, Ti 2·5, Al 0·8, Mn 0·6, Si 0·5, C 0·04, per cent.).

Hastelloy B (Ni 65, Mo 28, Fe 5, Mn<1, Si<1, V 0·4, C<0·12, per cent.).

Nickel-Chromium Steel Type 347 (Fe 67, Cr 18, Ni 10·5, Mn<2·0, Si<1·0, Nb 1·0, C<0·08, per cent.).

Ceramic Coating of High-Temperature Materials

'Recent Ceramic Coatings for High-Temperature Alloys.' *Nat. Bur. Standards, Tech. News Bull.*, 1951, vol. 35, Oct., pp. 145-7.

Ceramic coatings developed by the National Bureau of Standards are reported to be substantially increasing the service life of high-temperature alloys, particularly in the exhaust systems of aircraft. The most successful, and most widely used, of these coatings is A.417, which is a high-barium, alkali-free frit (glass) having a 30 per cent. admixture of chromic oxide. This composition was selected on the basis of results of laboratory experiments in which a variety of compositions was studied and tests were carried out to determine the effect of various chemicals, as well as heat, on ceramic-coated high-temperature materials.

The coating is applied in the form of a water suspension, or 'slip', and is then fired, resulting in formation of a smooth, uniform, green-coloured finish which can be applied in controlled thicknesses varying from 0·001 to 0·002 in. To date, the coating has been used mainly on Inconel and 19-9 DL alloy, but it has also been successfully applied to Haynes Stellite 21, S-816 alloy and 18-8 chromium-nickel steel, and the indications are that it is suitable for use on any of the common heat-resisting alloys. Methods of preparation of the coating material, application, and firing, are described in this article.

Metallographic examination of laboratory samples has shown that the A.417 coating retards absorption of carbon from exhaust gases of high fuel: air ratio, corrosion from lead compounds in the exhaust stream, and oxidation of exterior surfaces. The coating has good resistance to high-temperature flow and to thermal shock; it adheres well, even after prolonged heating at temperatures up to 1650°F. (900°C.), and effectively covers edges and welds.

Among the successful service experiences quoted are the use of coated Inconel heat exchangers in the exhaust system of a large bomber, to supply heated air for de-icing. In this application uncoated parts had been failing after only short service. Commercial airlines report that life expectancy of exhaust collector parts is increased by use of the coating, and as a result of their experience coated systems are now being produced in considerable quantity. Encouraging results have also been obtained in laboratory tests with coated gas-turbine blades, but data are at present limited. Further tests are in hand.

Other types of high-temperature ceramic coating are also being developed by the National Bureau of Standards: one of these, a chromium-frit, appears likely to prove useful for protection of molybdenum from oxidation at high temperatures.

See also 'Ceramic Coatings for Metal Protection at High Temperatures.' *Product Engineering*, 1951, vol. 22, Nov., pp. 177-9.

This article is based on the experience of the Stewart-Warner Corporation, in the use of ceramic coatings developed by the National Bureau of Standards, in aircraft exhaust systems. Three types of coating are being tried out:—

A.19 consists of 50 parts of a relatively soft or fusible frit, 50 parts of a hard or infusible frit, 25 parts of calcined alumina, 10 parts of enameller's clay, and other minor ingredients. This mixture, applied in thicknesses of 0·001 to 0·0025 in. on high-alloy materials such as 18-8 and 25-20 steels, Inconel, Stellite alloy and Multimet N-155, fires at 1650°F. (898°C.) and cannot be exposed for long periods above this temperature without deterioration. The coating is brittle, and must therefore be applied after the component has been fabricated.

A.417. For particulars of this coating, see previous abstract. Confirmatory evidence of its protective power is given in the present article.

A.520. This mixture is less brittle than A.19, but not so flexible as A.417. Firing temperature is 1750°F. (953°C.). At present no clear proof of any advantage in this mixture, in comparison with other types, has been adduced, and the coating has not been applied to production components.

Extensive use is ultimately anticipated for the ceramic coatings, in the range 1200°-1400°F. (650°-760°C.), e.g., for domestic heating apparatus. Coatings for abrasion-resistance at elevated temperature are another potential application, and the fact that some of the coatings have other useful properties, such as resistance to salt-spray, will probably further widen their field of usefulness.

Steels in Modern Industry: Textbook

See abstract on p. 45.

Induction Melting of Stainless Steel: Selenium Degasification

R. J. WILCOX: 'Induction Melting of Stainless Steels.' *Amer. Inst. Mining and Metallurgical Engineers, Proc. Eighth Electric Furnace Steel Conference*, 1950, pp. 115-18; disc., pp. 118-19.

Final form, with discussion, of paper abstracted, from *Jnl. of Metals*, in *Nickel Bulletin*, 1951, vol. 24, No. 1, pp. 18-19.

Recent Developments in Melting Practice for Stainless Steels

A. C. OGAN: 'Recent Trends in Stainless Melting Practice.' *ibid.*, pp. 120-22; disc., pp. 122-4.

A review, in very general terms, of some modifications in practice which are tending to improve productivity and quality. Reference is made, *inter alia*, to changes in furnace design and the trend towards top charging and increased power at the arc, the use of larger furnaces, the commercial establishment of technique for production of extra-low-carbon stainless steels (0·03% max. carbon), and the close control made possible by the use of large amounts of scrap of accurately known composition. The introduction of induction stirring in the arc furnace, as originally developed in Sweden, has been a method of improving homogeneity of stainless steels, and close control of addition elements, with improved recovery, is now a feature of commercial melting procedure. Methods introduced for improving the cleanliness of stainless steels have also been an important contribution to recent progress: reference is made to additions of Mischmetall and other rare-earth metals to obtain cleanliness and improved rolling properties, a development which has progressed since the date of this paper (see *Nickel Bulletin*, 1951, vol. 24, No. 8, p. 181). Improved control of bath temperature has also made an important contribution to progress in almost all electric-furnace melting shops.

Nickel Alloys in Heating Elements

F. J. LAMBERT: 'The Casting of Inconel Tubing Heaters in High-Copper Alloy.' *U.S. Atomic Energy Commission Publn. Y*-583, 1950; 28 pp.

cf. *Metal Progress*, 1951, vol. 59, June, pp. 889-91; *Nickel Bulletin*, 1951, vol. 24, No. 8, p. 180.

Properties of Stainless Steel Wire as a Function of Rate of Reduction

S. STORCHHEIM: 'Effect of Varying the Rate of Reduction on the Magnetic Properties, Ultimate Tensile Strength, and Resistivity of 18-8 Stainless Steel Wire.' *Jnl. of Metals*, 1951, vol. 3, Dec. (*Trans. Amer. Inst. Mining and Metallurgical Engineers*), pp. 1181-3: T.P. 3181 E.

Variations have been found in the magnetic properties (coercive force and remanence) of 18-8 wires of similar composition after given percentage reductions of area produced at different rates. In order to determine the extent of the variation so producible, tests were made in which commercial nickel-chromium steels of the 302 and 304 types were drawn at widely varying speeds. Differences in tensile strength, specific resistance and magnetic properties were measured in relation to speed of reduction.

In the first series of experiments two specimens were drawn, at speeds of 45 to 3900 ft. per min., directly from 0·016 in. dia. wire to 0·004 in dia., representing a 93·7 per cent. reduction in area. (In order to obtain this high percentage reduction, the wire was annealed, before drawing, at 1150°C. The special precautions adopted and methods used are described.) In later experiments two additional specimens of the same types of steel were drawn, from heavier initial sizes, to 84·4 per cent. reduction of area, having also been annealed prior to drawing. In these tests speeds of drawing ranged from 625 to 1150 ft. per min.

The results recorded confirm that all three properties studied are affected by speed of reduction. With increase in rate of drawing coercive force increased, while remanence, tensile strength and resistivity decreased. The changes in coercive force and remanence were quite extensive: those in tensile strength and specific resistance, although significant, were less. For a given rate of draw increase in nickel content was associated with higher coercive force and lower remanence and resistivity. Specimens of higher carbon contents showed higher tensile values for any given rate of reduction. The author suggests the following as a possible explanation for the observations made:—

'Cold working a metastable austenitic 18-8 stainless steel produces martensite, provided the temperature during working is not much higher than room temperature. During the process of drawing wire through a die or a series of dies, an increase in temperature of the wire occurs, because of the dual processes of deformation and friction. The wire generally will be cooled off by the coolant to approximately room temperature, in the time that it travels the distance from one die to the next. Should the temperature become greater, less martensite will be formed. Thus, if the speed of draw is increased to the point where the lubricant can no longer cool the wire fast enough, the temperature of the wire will rise above the room temperature. Therefore, the higher the drawing speed, the higher the temperature, the less martensite will be formed; consequently, the *Br*, resistivity, and tensile strength will be lower and the *Hc* will be higher.'

The author also suggests that the data reported indicate that modification of properties producible by control of drawing speeds might usefully be applied at the present juncture in order to condition such steels for specific applications for which 18-8 steel wire drawn under more normal conditions would not be suitable.

Nickel-containing Materials in Chemical Engineering: Literature Review

'Fifth Annual Chemical Engineering Materials of Construction Review.' *Industrial and Engineering Chemistry*, 1951, vol. 43, Oct., pp. 2193-294.

The review contains 15 articles covering literature dealing with metallic and non-metallic materials of construction which has been issued during the past year. Subjects covered include those shown below:—

H. W. FRITTS and E. D. VERINK: 'Aluminium Alloys.'

C. L. BULOW: 'Wrought Copper and Copper-base Alloys.'

C. P. LARRABEE and B. J. KELLY: 'Iron, Mild Steels and Low-Alloy Steels.'

D. B. BROUGHTON: 'Less Common Metals (Titanium, Zirconium, Tantalum, Molybdenum, Noble Metals).'

H. O. TEEPLE: 'Nickel and High-Nickel Alloys.'

This review covers alloys containing about 40 per cent. or more of nickel or appreciable quantities of cobalt. The subject matter is dealt with in three general sections: (1) development of new alloys or improvements in existing materials, and studies of their physical properties; (2) developments in the fabrication and working of nickel alloys; (3) developments in the applications of the alloys, with particular reference to the chemical and process industries. The *bibliography* contains 231 items.

A second section of this special supplement contains data on properties of some of the materials dealt with in the reviews. For the most part the particulars given are intended as a revision of data contained in the very comprehensive summary published with the reviews of 1948 and 1950. Also, the new tables extend the information given with regard to resistance to various forms of corroding chemical. Some of the additional information relates to nickel-chromium stainless steels.

Stainless Steels in Wine-Producing Plant

W. Q. HULL, W. E. KITE and R. C. AUERBACH: 'Modern Winemaking.' *Industrial and Engineering Chemistry*, 1951, vol. 43, Oct., pp. 2180-92.

A typical item in the 'Staff-Industry' collaborative Report' series in which this journal specializes. The history of the industry is outlined, the chemistry of winemaking is described, and the production of various types of wine, and their characteristics, are discussed.

Flow sheets and details of typical operating technique are given, based on practice at the plant of Roma Wine Company, Fresno, California, where various types of wine and spirit are produced.

Materials of construction used in wineries include bronze, stainless steels, copper, aluminium alloys. Stainless steels are increasingly favoured and are the most widely used type of special material.

A useful feature of the article is a glossary of terms used in the winemaking industry.

Hot-Cracking in Nickel-Chromium Austenitic Welds

E. C. ROLLASON and M. C. T. BYSTRAM: 'Hot-Cracking of Austenitic Welds, with Special Reference to 18-13-1 Cr-Ni-Nb Alloy.' *Jnl. Iron and Steel Inst.*, 1951, vol. 169, Dec., pp. 347-52.

It has been known for some years that welds in austenitic alloys containing 12-12 to 80-20 nickel-chromium were highly susceptible to cracking at elevated temperatures during the welding operation, and the need to fabricate large gas-turbine rotors by welding together small forgings, particularly in 18-13-1 chromium-nickel-niobium alloy has recently refocused attention on the problem.

The use of specially designed electrode coatings has minimized the risk of major hot cracks in this type of material, but elimination of all micro-cracking has proved more difficult. Austenitic plate is not so susceptible to cracking as is weld metal of similar composition, indicating the influence, on cracking, of segregations in the cast structure. It is believed that films of sulphide, silicate and carbides may have an effect, and metallic compounds may also be important. It is known that a niobium content exceeding four times the silicon content prevents cracking in 80-20 deposits.

In the light of the above experience and knowledge, the present authors made a study of the influence of grain size, strain, and heterogeneity (both coring and non-metallic forms), intermetallic compounds, and the presence of ferrite and of trace elements, on hot-cracking of austenitic nickel-chromium-containing weld deposits. Thirty-one specimens, of varying composition, were examined. They included alloys of duplex, as well as fully austenitic, structure.

Three types of test were used:—

(1) The Murex hot-crack machine, in which a single bead is strained, during deposition, by an external force. Controllable strains are obtainable, and cracks are opened, making etching unnecessary.

(2) The circular multi-run pad test, in which weld metal deposits on the end of a steel bar 2-in. dia. × 4 in. long. Normal contraction stresses and strains are involved, since there is little warping of the bar. The cracks are revealed by turning in a lathe and the surface is polished and etched.

(3) The longitudinal-pad test, in which pads are built up on flat bars, sectioned longitudinally, and etched. Restraint is lower than in test (2), the warping of the bar being analogous to that of a spring. Later beads may alter the stress-distribution resulting from earlier runs, and thus give rise to strain. Stress may also be accentuated by depositing beads on the face of the plate opposite the test welds.

Hot-bend and hot-tensile tests were also carried out, to determine the ductility of the respective compositions, in the various temperature ranges involved in welding and cooling.

The findings of the authors are illustrated by a series of photomicrographs and diagrams indicating the influence of structure and other variables on susceptibility to hot-cracking. The following conclusions are drawn:—

Micro-cracks in austenitic weld metals are intercrystalline, and occur mainly in beads of weld metal re-heated above 1250°C. Internal stresses and heterogeneity in structure are contributory factors.

Although sulphur reduces resistance to hot-cracking, it does not appear to be a major cause of micro-cracking. Other non-metallic inclusions were found to have but little effect.

Silicon appears to be a major contributory factor in promoting breakdown of boundary cohesion, but its influence is reduced if a sufficient amount is present to cause formation of ferrite. Addition of 1-1½ per cent. of niobium, and of carbon in excess of 0·09 per cent., is beneficial in reducing susceptibility to micro-cracking.

The presence of a minimum of about 5 per cent. of

ferrite obviates micro-cracking, but long exposure of ferrite-containing material in the range 650°-950°C. results in formation of sigma and associated embrittlement. Small amounts of sigma, of the order of 7 per cent., can safely be tolerated. The improvement found in the duplex-structure materials is attributed to accommodation of silicon in the ferrite lattice, greater boundary area, and a lack of coincidence of final boundaries and primary coring.

Water Cooling of Austenitic Unstabilized Welds

J. A. GOODFORD and D. W. KAUFMANN: 'Welding Unstabilized Austenitic Stainless Steels without Carbide Precipitation.' *Materials and Methods*, 1951, vol. 34, Nov., pp. 64-5.

A short note advocating the benefits of water-cooling, to secure rapid cooling of welds in unstabilized nickel-chromium austenitic steels, in order to prevent carbide precipitation and associated susceptibility to intergranular corrosion. The water can be applied from a hose (either as a spray or in a steady stream), or by swabbing with wet waste material or rag: cooling should be begun within a minute or so after the arc has been established, and spraying or swabbing should be continued until all colour disappears. Although the weld may be cooled in this way down to room temperature, it is generally advisable to leave enough heat to evaporate the water in the weld crater, in order to prevent occurrence of porosity when the arc is re-struck. Methods of water cooling are well illustrated in this note.

Water cooling may also be applied with advantage during gas-cutting operations or electric arc-cutting, and it is recommended when making multi-pass welds in stabilized grades of austenitic steel.

Determination of Tantalum and Niobium in 18-8 Stainless Steels

W. J. POEHLMAN and R. E. SARNOWSKI: 'Spectrographic Determination of Tantalum and Columbium in 18-8 Stainless Steels.' *Analytical Chemistry*, 1951, vol. 23, Nov., p. 1721 (Abs. of paper to Optical Soc. of America, Oct., 1951).

'A spectrographic method for the determination of the strategic and critical elements tantalum and niobium, covering the concentration ranges 0·01 to 0·40 per cent. and 0·30 to 1·25 per cent., respectively, was described. Samples are excited by an a.c. arc discharge, using the point-to-plane technique. A prism-type spectrograph is employed, and the resulting spectrograms are recorded on calibrated emulsions. Utilizing the iron matrix as an internal standard, photographic photometry readings and intensity-ratio comparisons are made for the analytical line pairs 3311·16 Ta *vs.* 3165·86 Fe and 3299·61 Cb *vs.* 3165·01 Fe. Included in the discussion were referee analyses, comparisons, working curves, and standards. The analytical results of this method indicate adequate sensitivity, precision, accuracy, and range of analysis for this type of material.'

Determination of Cobalt in High-Nickel Steels and Alloys

H. E. AFFSPRUNG, N. A. BARNES and H. A. POTRATZ: 'Spectrophotometric Determination of Cobalt as Tetraphenylarsonium Cobaltothiocyanate.' *Analytical Chemistry*, 1951, vol. 23, Nov., pp. 1680-3.

In experiments designed to develop a simple method for determining traces of cobalt in uranium materials, a procedure was devised which involves separation of cobalt from aqueous solution by chloroform extraction of tetraphenylarsonium cobaltithiocyanate and spectrophotometric determination of the cobalt content of the chloroform extract. This paper reports tests in which the procedure was studied with respect to its applicability to the analysis of other materials, particularly alloy steels and nickel-copper alloys. Directions are given for estimation of cobalt in such materials without prior separation of copper, iron, nickel, chromium and other constituents of the alloy solutions.

The method is rapid and convenient. Its accuracy is demonstrated by results of determinations on National Bureau of Standards samples of 18-8 steel, 35 per cent. nickel steel, a chromium-molybdenum-tungsten steel, a nickel-chromium-iron alloy, and an alloy of Monel type.

Determination of Titanium in Stainless Steels

A. I. KOKORIN: 'Photoelectric, Semi-Microdetermination of Titanium in Acid-Resisting Steel.' *Zavodskaya Laboratoriya*, 1950, vol. 16, pp. 777-80.

The author describes a qualitative colorimetric semi-micromethod for estimation of titanium, based on reduction of silico-molybdate by trivalent titanium. The advantages of molybdenum blue over the yellow pertitanic colour are urged, with regard to colorimetric determination of intensities, and the superiority of the semi-micro method, as compared with the macro method, is emphasized.

Nickel-Copper Alloys in Kuwait Water-Distillation Plant

See abstract on p. 42.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

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